Cluster model and structure in the two-particle rapidity plane in inclusive and semi-inclusive correlations

G. Ranft

CERN -- Geneva

and

Sektion Physik - Karl-Marx-Universität Leipzig, DDR

Abstract : Detailed study of the structure in the rapidity plane allows to determine the amount of single and double diffraction within a cluster model. From semi-inclusive data on correlations the average number of particles due to decay of one cluster can be estimated.

Résumé : L'étude détaillée de la structure dans le plan de rapidité permet de déterminer la quantité de diffraction simple et double dans un modèle de "cluster". On peut estimer le nombre de particules provenant de la désintégration du "cluster" à partir des données semi-inclusives de corrélations.

Data on inclusive single particle spectra and correlations can be explained well by the multi cluster model. In this model the short range component is due to production of several clusters probably in a multiperipheral mechanism and a long range component is described by diffractive one and two cluster production. From the data on rapidity correlations it was deduced that the average mass of a cluster is $\langle M \rangle \simeq$ const, independent of energy. Table 1 lists various possibilities for the average cluster mass together with their consequences /1,2/.

The inclusive divided two-particle correlation function is

$$R_2(y_1, y_2) = \frac{\frac{1}{\sigma}\frac{d^2\sigma}{dy_1 dy_2}}{\frac{1}{\sigma^2}\frac{d\sigma}{dy_1}\frac{d\sigma}{dy_2}} - 1 \qquad (1)$$

From the measured central value $R_2(0,0)$ which essentially remaines unchanged from energies at Serpukhov to ISR an average mesonic cluster mass of $\langle M \rangle \simeq 2$ to 2.5 GeV has been determined /3/.

In the rapidity plane a complicated structure has been found at ISR /4/ and NAL energies /5/. This structure can be explained by the superposition of non-diffractive (ND) and single (D,1) and double (D,2) diffractive mechanisms /3a/, see Figure 1.

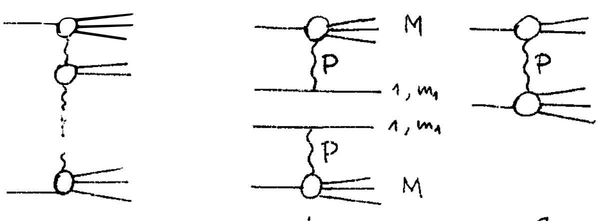

Fig. 1

In the following we line out how to obtain the two-particle distributions needed to compute $R_2(y_1,y_2)$. The single particle distribution can be obtained within a similar spirit. It is

$$\frac{1}{\sigma}\frac{d^2\sigma}{dy_1 dy_2} = \alpha\frac{d^2N_{ND}}{dy_1 dy_2} + \beta\frac{d^2N_{D,1}}{dy_1 dy_2} + (1-\alpha-\beta)\frac{d^2N_{D,2}}{dy_1 dy_2} \qquad (2)$$

The non-diffractive term (ND) contains the term with both particles emerging from one cluster with rapidity η

$$\frac{d^2 N_{ND,1}}{dy_1 dy_2} = \int_{-\eta_-}^{\eta_+} F_{ND}(\eta, s) \frac{dn(\eta,s)}{dy_1} \cdot \frac{dn(\eta,s)}{dy_2} d\eta \qquad (3)$$

and the term with both particles emerging from two different clusters with rapidities η_1 and η_2

$$\frac{d^2 N_{ND,2}}{dy_1 dy_2} = \int_{-\eta_-}^{\eta_+} \int F_{ND}(\eta_1, s) F_{ND}(\eta_2, s) \frac{dn(\eta_1,s)}{dy_1} \frac{dn(\eta_2,s)}{dy_2} d\eta_1 d\eta_2 . \qquad (4)$$

In these expressions we have assumed

i) uncorrelated decay of a cluster, expressed by factorisation of the one-cluster decay function in Eq. (3)

ii) uncorrelated production of clusters, expressed by factorisation of the production function of two clusters in Eq. (4).

For the cluster decay function we use

$$\frac{dn(\eta,s)}{dy} = g \langle M \rangle \exp\left(-\frac{|\eta - y|}{a}\right) \qquad (5)$$

and for the production function of one cluster we use

$$F_{ND}(\eta,s) = \frac{1}{\langle M \rangle}\left[1 - \exp\left(-\frac{|\eta - \eta_\pm|}{A_{ND}}\right)\right. \qquad (6)$$

$\eta_\pm$ are the kinematic limits for the production of non-diffractive clusters. The constants g and A_{ND} are determined from single particle spectra.

We remark that the two-cluster expression (4) factorizes in a product of single particle spectra. Therefore, to the central value of the correlation function $R_2(0,0)$ only the one-cluster term contributes. It is

$$R_2(y_1, y_2) = \frac{\langle M \rangle}{4B} \exp\left(-\frac{|y_2 - y_1|}{a}\right)\left(\frac{1}{a} + \frac{|y_2 - y_1|}{a}\right) \qquad (7)$$

which allows to determine the average cluster mass $\langle M \rangle$ and the correlation length $a = \lambda \sim 1.5 \pm 0.2$. From data on $R_2(0,0)$ it follows

$\langle M \rangle \gtrsim 2$ GeV. The contribution (7) is shown schematically in Figure 2.

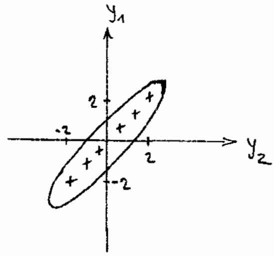

Figure 2

The diffractive graph (Fig. 1b) describes correlations of one fast particle (particle 1 in Fig. 1b) with one particle with rapidity y emerging from the cluster. The rapidities y_1 and η of the leading particle and of the cluster, respectively, are connected by kinematics

$$y_1' = \cosh^{-1}\left(\frac{M}{m_1}\cosh\eta - \frac{\sqrt{s}}{m_1}\right) \tag{8}$$

The two-particle rapidity distribution in the single diffractive case is then for a forward moving cluster

$$\frac{d^2N_{D,1}}{dy_1\,dy} = \int_0^{\eta_+} d\eta\, F_{D,1}(\eta,s)\,\delta\big(y_1 - y_1'(\eta)\big)\,\frac{dn(\eta,s)}{dy} \tag{9}$$

with the production function of a diffractive cluster

$$F_{D,1}(\eta,s) = B_{D,1}\exp\left(-\frac{\eta_+ - \eta}{A_{D,1}}\right) \tag{10}$$

Again, $B_{D,1}$ and $A_{D,1}$ are determined from single particle spectra. A similar term contributes for a backward moving cluster. The correlation function due to the single diffractive terms behaves as in Fig. 3 .

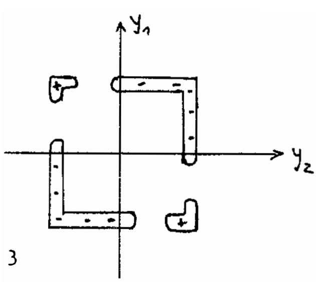

Figure 3

In the diffractive two-cluster production with masses M_1, η_1 and M_2, η_2 these clusters are constrained by kinematics

$$M_1(\eta_1,\eta_2) = \sqrt{s}\left[\cosh\eta_1 - \sinh\eta_1\,\mathrm{ctgh}\,\eta_2\right]^{-1}. \tag{11}$$

Factorization of the diffractive cluster production function $F_{D,2}(\eta_1,\eta_2,s) = F_{D,1}(\eta_1,s)\, F_{D,1}(\eta_2,s)$ with the functions $F_{D,1}(\eta,s)$ given in Eq.(10) leads to the two-particle spectrum

$$\frac{d^2 N_{D,2}}{dy_1 dy_2} = \int_{\eta_-^{(2)}}^{\eta_+^{(2)}} d\eta_1 \int_{\eta_2^-}^{\eta_2^+} d\eta_2\, F_{D,1}(\eta_1,s)\, F_{D,1}(\eta_2,s) \frac{dn(\eta_1,s)}{dy_1} \frac{dn(\eta_2,s)}{dy_2}$$

$$\underset{s\to\infty}{\sim} \exp\left(\frac{y_1+y_2}{c} \right) \qquad (13)$$

This function behaves as in Fig. 4. Thus a two-component model on particle production can explain the structure seen in the inclusive rapidity plane. More precise data as they are becoming available now from ISR and NAL should allow to determine the amount of single and double diffraction, i.e., the parameters α and β in Eq. (2).

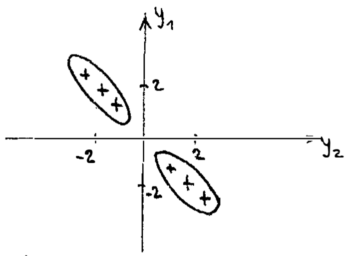

Figure 4

The assumption of uncorrelated cluster production and uncorrelated decay used above entails not only factorisation of the cluster production and decay functions but also a Poisson like multiplicity distribution both for the produced cluster as well as for the decay products of one cluster. With these assumptions it is also possible to explain the recent data /4/ on semi-inclusive rapidity correlations as a function of multiplicity /6/. The essential parameter for these correlations is the number of particles produced per average cluster. From comparison with experiment /4/ one finds that the charged multiplicity of a cluster is about 2.5 to 3.5.

The results summarized here have been obtained in collaboration with J. Ranft.

References

/1/ J. Ranft and G. Ranft, Nucl. Phys. B53 (1973) 217.

/2/ J. Kripfganz, G. Ranft and J. Ranft, Nucl. Phys. B56 (1973) 205.

/3/ see, e.g.,

a) G. Ranft and J. Ranft, Phys. Letters 45B (1973) 43.

b) F. Hayot and A. Morel, Saclay preprint (1973).

c) W. Schmidt-Parzefall, Phys. Letters 46B (1973) 399.

/4/ L. Foà, Talk at the II Internat. Conference on Elementary Particles in Aix-en-Provence, 1973.

/5/ R. Singer et al., Argonne preprint ANL/HEP 7368 (1973).

/6/ G. Ranft and J. Ranft, Phys. Letters to appear (1974).

/7/ A. Bassetto, G. Ranft and J. Ranft, Nuovo Cim. Lett. 5 (1972) 841 and Karl-Marx-University preprint KMU-HEP 7309 (1973).

Table 1 : Consequences of the s behaviour of the average cluster mass

$\langle M \rangle$	Number of clusters	Central plateau in y_1, y_2 plane	Multiplicity distribution
$\sim \ln s$	ln ln s	rises with s	asymptot. KNO scaling /7/
$\sim \left(\sqrt{s}\, e^{-\lvert\eta\rvert}\right)^{w}$ $0 < w \leq 1$	const.	singular at $y_1 = y_2 = 0$	see Diffract. Excit. Model
const.	ln s	const.	practical KNO scaling /2/